PUBLICATION 783 ISSUED AUGUST, 1946
TECHNICAL BULLETIN 56 FIRST PRINTING
DOMINION OF CANADA—DEPARTMENT OF AGRICULTURE

STUDIES IN FOREST PATHOLOGY

IV.

DECAY OF SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

J. E. BIER,
R. E. FOSTER, AND P. J. SALISBURY

DIVISION OF BOTANY AND PLANT PATHOLOGY
SCIENCE SERVICE

Published by authority of the Hon. JAMES G. GARDINER, Minister of Agriculture,
Ottawa, Canada

2M—9473—8-46

ERRATA

p. 15—9th line "that" should read "than"

p. 16—1st line, parenthesis missing after "Schweinitzii".

p. 17—12th line should read, "in causing dry rot in timber. Further it is evident that these decays are"

p. 18—end of line 9 insert period.

p. 20—8th line from bottom, "analyzed" should read "analysed"

p. 30—1st sentence, the word "is" should be transposed to appear before "given"

p. 32—2nd line "Grade A" should read "Grade 3"
—12th line from bottom, "present" should read "presence"
—4th line from bottom, "and" should read "an".

p. 34—last line, insert period after the parenthesis mark following "Mill".

p. 35—5th line from bottom, insert a period instead of comma after "fir".

Plate 3—"Kauffanii" should be "Kauffmanii".

Plate 6—"pini" should be "Pini".

Plate 10—"laricis" should be "Laricis," and "Jack." should read "Jacq".

81654

PUBLICATION 783 ISSUED AUGUST, 1946
TECHNICAL BULLETIN 56 FIRST PRINTING

DOMINION OF CANADA — DEPARTMENT OF AGRICULTURE

STUDIES IN FOREST PATHOLOGY

IV.

DECAY OF SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

J. E. BIER,
R. E. FOSTER, AND P. J. SALISBURY

DIVISION OF BOTANY AND PLANT PATHOLOGY
SCIENCE SERVICE

Published by authority of the HON. JAMES G. GARDINER, Minister of Agriculture,
Ottawa, Canada

67715—1

TABLE OF CONTENTS

STUDIES IN FOREST PATHOLOGY

IV. Decay of Sitka Spruce on the Queen Charlotte Islands[1]

J. E. Bier,[2] R. E. Foster,[3] and P. J. Salisbury[4]

INTRODUCTION

In 1942 a number of requests were received from the logging industry, British Columbia Forest Service, British Ministry of Supply, and Office of Timber Control, for information on the decays which occur in Sitka spruce *(Picea sitchensis* (Bong.) Carr.) on the Queen Charlotte Islands. Particular reference was made to a disease locally known as pocket rot, which was reported to have been serious in some localities.

Examination of the literature pertaining to the rots of Sitka spruce and correspondence with pathologists in the United States did not disclose any reference to a decay of the pocket-rot type. Further, it became evident that comparatively little was known of the losses from decay in stands of Sitka spruce in British Columbia.

The paramount effort on the part of the industry to meet the tremendous demand for this spruce in aeroplane construction emphasized the need for investigations to obtain additional information on decay. At present the industry is operating in mature and overmature timber, which, because of its size and age, should yield an appreciable percentage of clear lumber suitable for aeroplane construction. Since the timber is old, losses from decay may be expected. Therefore, the purpose of this work was not to stress the amount of cull in stands, but to ascertain data which would assist in obtaining the maximum recovery by grade from timber known to contain more or less defect.

Accurate inventories, efficient utilization, and management of overmature forests of this type are dependent in part upon a knowledge of the external indications, incidence, and amount of decay. Further, as the area of existent stands is decreasing rapidly, it is imperative that full advantage should be taken of the remaining timber. The results achieved may be of value to the timber cruiser in estimating for defect in uncut stands, and indirectly may serve as a guide to the industry when consideration is given to the many factors which determine whether marginal stands are of commercial value.

In order to avoid undue delay in presenting the results of current investigations annual reports were distributed to the interested agencies. The present paper summarizes all work which has been undertaken on this project during the past three years.

---

[1] Contribution from the Dominion Laboratory of Forest Pathology, 714 Belmont Building, Victoria, British Columbia.
[2] Forest Pathologist.
[3] and [4] Assistants in Forest Pathology.

THE FOREST RESOURCES OF THE QUEEN CHARLOTTE ISLANDS

According to the Reports of the Forest Branch of British Columbia for the years 1938 and 1939 (20, 21) the total merchantable[5] timber on the Queen Charlotte Islands was estimated to amount to 11,530,840,000 board feet, of which 94 per cent was classified as accessible. The proportion of the different species comprising this volume was as follows:—

western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	—46 per cent
Sitka spruce	—34 per cent
western red cedar (*Thuja plicata* D. Don.)	—18 per cent
yellow cedar (*Chamaecyparis nootkatensis* (Lamb.) Spach.)	— 2 per cent

Prior to 1939 the annual cut averaged a little over 80,000,000 board feet, practically all of which was obtained from the Moresby group of the Islands. During the war years, 1940 to 1943 inclusive, the annual cut averaged 155,000,000 board feet[6] or approximately twice the normal output. The utilization was concentrated in stands that occurred in the valley bottoms and on the gentle slopes, and which contained the greatest volume of spruce. On the average over 50 per cent of the annual cuts was composed of this species.

The Queen Charlotte Islands are regarded as a potential pulp-wood and saw-timber unit and have been established as a Provincial Forest. It is estimated that the accessible, stocked areas in the unit have a sustained yield capacity of approximately 187,000,000 board feet annually.

REVIEW OF PREVIOUS INVESTIGATIONS

By the end of the first World War, Sitka spruce was recognized as a valuable wood for aeroplane construction. The exacting specifications for air-grade timbers led to a number of investigations on the recognition and significance of the decays in the wood of Sitka spruce.

In 1921 Colley (8) reported that the incipient decay of *Trametes pini* had less effect on the mechanical properties of Sitka spruce than the early decays caused by *Fomes pinicola, Fomes laricis,* and *Polyporus Schweinitzii.* A bulletin by Cary (7) in 1922 on the uses, growth, and management of Sitka spruce included a section, prepared in collaboration with the author, by Dr. J. S. Boyce on the decays which occurred in living trees. *T. pini* was mentioned as the fungus causing the most serious loss from decay. *Polyporus Schweinitzii* and *F. pinicola* were considered next in importance. It was stated that Sitka spruce was much less subject to decay than western hemlock or Douglas fir, and that trees up to 200 years of age were remarkably free from decay. In 1923 Boyce (3) discussed the decays and discolorations of a number of aeroplane woods including Sitka spruce. Descriptions were included of the decays caused by *T. pini, F. laricis, P. Schweinitzii,* and *P. sulfureus.*

During 1925 reports from England stated that serious losses from decay were being found in shipments of Sitka spruce from Canada. Mounce (17) investigated the problem and reported that the cultures of the primary organisms

[5] Merchantable defined as trees over 11 inches D.B.H.

[6] Figures for the annual cuts for the years 1940 to 1943 were kindly provided by Mr. F. S. McKinnon, Forester, Economics Division, British Columbia Forest Service.

responsible for the decays in England were identical with those obtained from specimens of freshly sawn Sitka spruce in Canada. The major species included *P. Schweinitzii* and two unknown fungi whose cultures were considered to be very characteristic. It was concluded that these fungi may all occur in standing, living trees or freshly felled timber, and that they were probably present in the Sitka spruce lumber before it was shipped from the Pacific Coast to England. Following a cultural investigation into the decays of Sitka spruce in England, Cartwright (5) stated in 1930 that a fungus identified as *Trametes serialis* Fr. occurred in a great majority of the decayed specimens collected. From the descriptions of the rot and culture it was considered that *T. serialis* was one of the unknown fungi previously isolated by Dr. Mounce in Canada. *P. Schweinitzii* and two other Basidiomycetes of slighter importance were also cultured from infected wood in England.

In 1941 Scheffer, Wilson, Luxford, and Hartley (25) reported on the effect of *Fomes pini, P. Schweinitzii,* and *F. laricis* on the specific gravity and strength of Sitka spruce and Douglas fir. It was found that the progress of strength reduction by *P. Schweinitzii* and *F. laricis* was not marked by any definite changes in the appearance of the wood. In the case of decay by *F. pini* the beginning of the formation of white pockets marked a fairly definite stage in the progress of strength reduction and could be used as a guide. Further, it was apparent that sound wood close to infections by *F. pini* and *P. Schweinitzii* was normal in strength properties, thus indicating the possibility of using the high-grade material in diseased trees. The difficulty of distinguishing incipient decay was stressed, showing the necessity of devising some reliable test for detecting decay in its early stage.

In 1942 Baxter and Varner (1) reported that as the result of investigations in Alaska it was evident that Sitka spruce was subject to attack by a number of fungi other than *P. sulphureus, F. pini, P. Schweinitzii, F. pinicola, F. laricis,* and *T. serialis,* which had been recorded previously in the literature. Mention was made of *Polystictus abietinus* Dicks., *Fomes annosus* Fr., *Polyporus anceps* Pk., *Trametes alaskana* Baxter, *Trametes variiformis* Pk., *Trametes heteromorpha* Fr., *Poria sitchensis* Baxter, *Poria crustulina* Bres., *Poria subacida* Pk., *Polyporus alboluteus* Ell. and Ev., *Fomes nigrolimitatus* Romell, and *Poria xantha crassa* Karst. No indication was given concerning the incidence or relative importance of the different fungi as wood destroyers in living trees. General observations suggested that *P. sulphureus* and *F. pini* occurred on the most limby trees, and that *F. pinicola* was not common in living trees.

In 1943 Nobles (19), reporting on material collected during the course of this investigation, demonstrated that the fungus on Sitka spruce previously considered as *T. serialis* by Cartwright (5) and Baxter and Varner (1) was actually a distinct species which was described as *Poria microspora* Overholts. However, in addition to *P. microspora,* authentic *T. serialis* also occurred in living Sitka spruce on the Queen Charlotte Islands.

As an aid to timber inspectors in the United States, Hansbrough and Englerth (11) in 1944 reported on the significance of various discolorations which were obtained in a survey of Sitka spruce wood. Tests for toughness were conducted on discoloured and non-discoloured samples from the same boards.

In 1946 Bier and Nobles (2) described brown pocket rot of Sitka spruce and, on the basis of constant association of the fungus with the decay and of the identity of cultures obtained from spores and context of the fruiting bodies and from the decayed wood, concluded that it was caused by *Lentinus Kauffmanii.* The original description of this fungus by Dr. Alexander H. Smith and its cultural characteristics are given.

LOCATION OF STUDIES

The field work reported in this study was undertaken on a number of logging operations on the Queen Charlotte Islands shown in figure 1 as follows:—

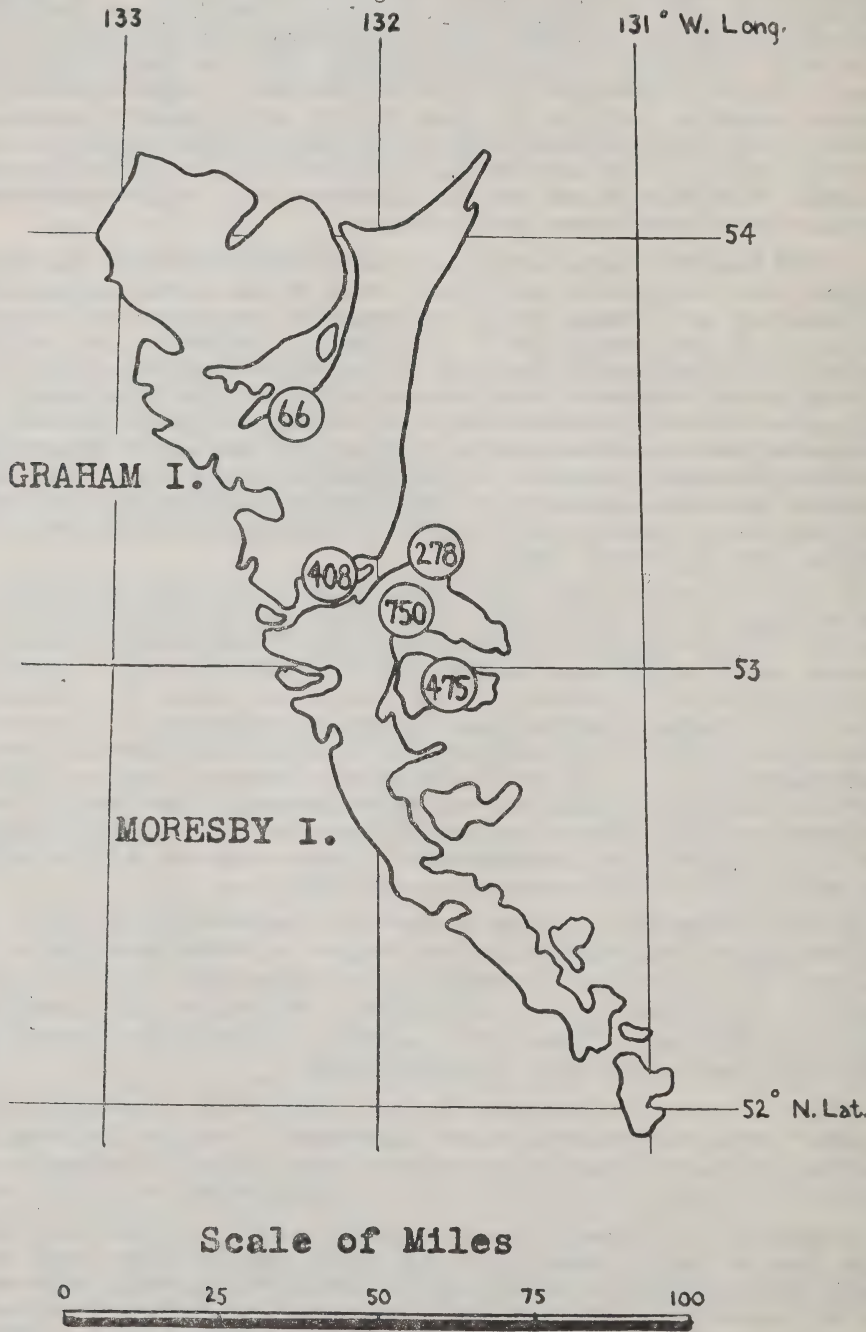


Figure 1.—Queen Charlotte Islands, B.C. The circles represent the approximate location of the areas studied. The numbers in the circles give the total number of trees analysed in each area.

475 trees analysed on Louise Island
750 trees analysed in the vicinity of Skidegate Lake
278 trees analysed in the vicinity of Sandspit
408 trees analysed in the vicinity of Skidegate Inlet
66 trees analysed in the vicinity of Masset Inlet

A majority of the logging camps were located on the Moresby group of the Islands, and, consequently, the sample of trees from this region was considerably higher than that for Graham Island.

METHOD OF STUDY

Sample Areas

Sample areas were established in the felled and bucked timber on the logging operations. The size of the areas varied in accordance with local conditions, such as area of the patch of timber felled, width of the cutting strips, and location of creeks and roads. The areas selected were considered to contain a sufficient number of trees to serve as an adequate sample of the timber in the different localities. Since part of the work was conducted in areas selectively logged, in which all the spruce had not been felled, it was not possible to convert the data to a stand or volume per acre basis. Further, some trees which were thought to be highly defective were not cut. This indicates that the percentage loss from decay as given in this study may be somewhat less than the actual. It is of importance to point out that the data given apply to the condition of trees which according to forest practice were believed to be of economic value on the basis of present standards of utilization. These trees comprised the major part of the spruce in overmature, uneven-aged stands.

Scaling and Grading

The logs of all the felled spruce on the sample areas were scaled and graded[7] from the point at which they were cut to a 12-inch top. For the purpose of this study the volumes calculated from the above were considered as the gross merchantable volumes of the trees. Deductions in grade were limited to those arising from visible defects, which were evident before the trees were felled. This included defects such as knots, crooks, spiral grain, conks, and swollen knots. Volumetric reductions were computed for the scaled and graded logs to allow for decay. In this way it was thought possible that factors might be derived which would cover the losses from decay in stands of different ages and types.

Tree Ages

The stump age was determined for each tree. In instances where a large amount of butt rot was present which made it impossible to obtain a complete ring count, the age was considered comparable with that of adjacent trees of a similar diameter and ring pattern. The total ages were computed by adding to the stump ages the estimated number of years it took the trees to grow to the measured stump heights.[8]

---

[7] The scaling and grading was undertaken in accordance with the standard practice outlined in the British Columbia Log Scale (24) and Scaling Lessons (23), and the Table of Grades for Spruce as incorporated in the Forest Act of British Columbia (22).

[8] Data on an age-height relationship for spruce seedlings and saplings were kindly provided by Mr. J. L. Alexander of the British Columbia Forest Service.

FOREST TYPES

In general the trees analysed in this work appeared to fall into two types which agree with those described by Hall (12) in a forest survey of Moresby Island. The types may be defined briefly as follows:—

(*a*) *Bench Type*—More open stands of spruce at the lower elevations in valley bottoms and on gentle slopes to creeks, lakes, and salt water. For the most part the areas are well drained. The spruce have a large diameter, but frequently are not so tall as those of the slope type. Typically the stand contains scattered, old-growth spruce, with an understory of western hemlock and spruce.

(*b*) *Slope Type*—Dense stands of hemlock, spruce, and western red cedar which occur on the steeper side hills. Hemlock appears to be the predominant species. Although the slopes provide excellent drainage the soil retains sufficient moisture to support a good growth of spruce. The trees are taller and less limby than those of the bench type.

THE FUNGI CAUSING DECAY IN SITKA SPRUCE

Early in the study cultural investigations indicated that Sitka spruce was subject to decay by a number of fungi which had not been recorded previously in living trees. These included organisms such as *Trametes serialis* and *Poria microspora* which were known to be of considerable importance as destroyers of timber in service. Further, it became evident that it was impossible to distinguish by visual examination of the decays on the ends of logs these brown cubical rots from others which occurred in Sitka spruce. In order to obtain more data on the incidence and relative importance of the different rots, cultures were prepared from all decays that could not be determined positively in the field. This work demonstrated that overmature Sitka spruce is attacked by many wood-destroying fungi.[9] A list of the fungi which were found associated with decay in living Sitka spruce is presented in table 1.

In addition to the fungi given in table 1 several other wood-destroying fungi were found on dead trees and slash. Further work may show that some of these are capable of causing decay in living trees. The additional fungi that occurred on dead material may be listed as follows:—

Lenzites saepiaria (Wulf.) Fr.
Peniophora dryina (B. and C.) Rog. and Jacks.
Polyporus alboluteus E. and E.
Polyporus cutifractus Murr.
Polyporus lapponicus Rom.
Polyporus picipes Fr.
Polyporus undosus Pk.
Poria nigrescens Bres.
Poria xantha (Fr.) Cke.
Stereum abietinum Pers.

The above list does not include two species of *Corticium*, one of *Odontia*, one of *Peniophora*, and three of *Poria* which are undetermined at the present time.

---

[9] The authors wish to express their sincere appreciation to Dr. L. O. Overholts, Department of Botany, Pennsylvania State College, to Dr. H. S. Jackson, Department of Botany, University of Toronto, and to Dr. Mildred K. Nobles, Division of Botany and Plant Pathology, Dominion Department of Agriculture, for the confirmation and identification of sporophores and cultures which were obtained during this study.

TABLE 1.—THE FUNGI CAUSING DECAY IN LIVING SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

Root and Butt Rots
- *Armillaria mellea* (Vahl) Quél.
- *Fomes applanatus* (Pers.) Wallr.
- *Fomes annosus* (Fr.) Cke.
- *Ganoderma oregonense* Murr.
- *Polyporus Berkeleyi* Fr.
- *Polyporus borealis* Fr.
- *Polyporus guttulatus* Pk.
- *Polyporus montanus* (Quél.) Ferry
- *Polyporus osseus* Kalchbr.
- *Polyporus tomentosus* var. *circinatus* Fr.
- *Polyporus Schweinitzii* Fr.
- *Poria albipellucida* Baxter
- *Poria asiatica* (Pilát) Overh.
- *Poria colorea* Overh. and Englerth
- *Poria subacida* (Pk.) Sacc.

Brown Pocket Rot
- *Lentinus Kauffmanii* A. H. Smith

White Trunk Rots
- *Fomes nigrolimitatus* (Rom.) Egel.
- *Fomes Pini* (Thore) Lloyd (*Trametes pini* (Thore) Fr.)

Brown Trunk Rots
- *Echinodontium tinctorium* E. & E.
- *Fomes Laricis* (Jacq.) Murr.
- *Fomes pinicola* (Swartz) Cke.
- *Omphalia campanella* (Fr.) Quél.
- *Peniophora luna* Rom.
- *Polyporus fibrillosus* Karst.
- *Polyporus sulphureus* (Bull.) Fr.
- *Poria microspora* Overh.
- *Poria subincarnata* (Pk.) Murr.
- *Stereum sanguinolentum* A. and S.
- *Trametes serialis* Fr.

Sap Rots
- *Polyporus abietinus* (Dicks.) Fr.
- *Polyporus volvatus* Pk.

OCCURRENCE OF THE FUNGI CAUSING DECAY IN LIVING TREES

Although many fungi caused decay in living trees, relatively few of these were of common occurrence (table 2). A total of 1,414 infections were found in the 1,977 trees analysed.

TABLE 2.—OCCURRENCE OF THE DIFFERENT WOOD-DESTROYING FUNGI IN LIVING SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

(Basis—1,977 trees)

Organism	No. of infections		Percentage of total number of infections	
Root and Butt Rots	386		27·29	
Polyporus Schweinitzii		223		15·78
Poria subacida		104		7·36
Poria colorea				
Fomes annosus		9		0·64
Armillaria mellea		8		0·57
Polyporus borealis		7		0·50
Polyporus tomentosus var. *circinatus*		6		trace*
Polyporus montanus		2		trace
Polyporus Berkeleyi				
Ganoderma oregonense		2		trace
Polyporus guttulatus		2		trace
Fomes applanatus		1		trace
Poria albipellucida		1		trace
Poria asiatica		1		trace
Polyporus osseus		1		trace
Unknown		19		1·34
Brown Pocket Rot	91		6·44	
Lentinus Kauffmanii		91		6·44
White Trunk Rots	354		25·05	
Fomes Pini		354		25·05
Fomes nigrolimitatus		3†		
Brown Trunk Rots	480		33·97	
Fomes pinicola		197		13·94
Trametes serialis		119		8·42
Poria microspora				
Polyporus sulphureus		78		5·52
Fomes Laricis		48		3·39
Echinodontium tinctorium		8		0·57
Poria subincarnata		4		trace
Peniophora luna		3		trace
Polyporus fibrillosus		2		trace
Stereum sanguinolentum		2		trace
Omphalia campanella		1		trace
Unknown		18		1·27
Sap Rots	6		trace	
Polyporus abietinus		6		trace
Polyporus volvatus				
Mixed Decay	97		6·86	
Total	1,414		100·00	

* Trace, less than 0·50 per cent.
† The 3 trees infected by *F. nigrolimitatus* did not occur on the areas included in the survey.

Root and butt rots were responsible for 27·3 per cent of the total number of infections. Of the fifteen fungi recorded as producing decay in the roots and basal portion of the trees, *Polyporus Schweinitzii* (brown butt rot) was the most common, having caused over 15·0 per cent of the total number of infections (plate I). Most of the remaining basal infections were caused by the white rots *Poria subacida* (stringy butt rot) and *Poria colorea* (spongy butt rot) as illustrated in plate II.

In the areas examined *Lentinus Kauffmanii* (brown pocket rot) was of general distribution, but could not be regarded as serious in any locality (plates III, IV, and V). Conclusive evidence was lacking to substantiate the belief that the disease occurs in patches, causing the total loss of all trees in isolated areas. *L. Kauffmanii* caused 6·4 per cent of the total number of infections.

In the survey all of the loss from the white trunk rots was caused by *Fomes Pini* (red ring rot). This fungus was responsible for 25·0 per cent of the total number of infections (plate VI). The decay resulting from infection by *Fomes nigrolimitatus* was found in three living trees not included in the survey.

Fomes pinicola (brown crumbly rot) was the most frequent of the eleven brown trunk rots, having been responsible for 13·9 per cent of the total number of infections (plate VII). This is of importance since in many instances this fungus has been regarded as of minor importance as a wood-destroyer in living trees. Undoubtedly, *F. pinicola* is one of the most common organisms inhabiting dead material, and is of considerable value as a destroyer of slash. On a basis of number of infections the dry rot fungi (*Trametes serialis* and *Poria microspora*) ranked second in importance to *F. pinicola* (plates VIII and IX). It should be mentioned that these organisms are known to remain viable in air-seasoned lumber for long periods, and frequently have been recorded as serious destroyers of wood in service. The dry rot fungi caused 8·4 per cent of the total number of infections. The brown cubical rots caused by *Polyporus sulphureus* and *Fomes Laricis* were next in importance to the dry rots, having been responsible for 5·5 and 3·4 per cent of the total number of infections (plate X). The remainder of the brown trunk rots occurred more infrequently. It is pointed out that in the absence of sporophores it was not possible in many instances to distinguish the different brown trunk rots from the appearance of the decays on the ends of logs. The figures given in table 2 were derived largely from the determination of cultures which were prepared from the different decays.

The sap rots were uncommon, occurring on the dead wood associated with scars. The infections listed as mixed decay were comprised of watery, indeterminable types of decay which frequently were present in dead tops and open scars.

METHODS OF ENTRANCE OF THE DECAYS

Prior to a discussion of the relative importance of the major fungi causing decay it is of interest to describe the methods by which they may enter healthy trees. Frequently this information is of value since it indicates the approximate location of the different decays in infected trees. A summary of the methods of infection of the fungi causing decay in Sitka spruce is given in table 3.

Table 3.—Methods of Entrance of the Decays in Sitka Spruce on the Queen Charlotte Islands

(Basis—1,977 trees)

Organism	No. of infections	Entrance of Infection Percentage			
		Roots	Tree scars	Branches	Dead tops
Root and Butt Rots—					
Polyporus Schweinitzii	223	86	11	....	3
Poria subacida } *Poria colorea* }	104	85	15	....	....
Fomes annosus	9	67	33	....	....
Armillaria mellea	8	75	25	....	....
Polyporus borealis	7	86	....	14	....
Polyporus tomentosus var. *circinatus*	6	33	67	....	....
Polyporus montanus } *Polyporus Berkeleyi* }	2	100	....	....	....
Ganoderma oregonense	2	100	....	....	....
Polyporus guttulatus	2	100	....	....	....
Fomes applanatus	1	100	....	....	....
Poria albipellucida	1	100	....	....	....
Poria asiatica	1	100	....	....	....
Polyporus osseus	1	....	100	....	....
Unknown	19	75	25	....	....
Brown Pocket Rot—					
Lentinus Kauffmanii	91	56	36	3	5
White Trunk Rots—					
Fomes Pini	354	....	7	89	4
Brown Trunk Rots—					
Fomes pinicola	197	....	83	15	2
Trametes serialis } *Poria microspora* }	119	....	41	28	31
Polyporus sulphureus	78	....	81	12	7
Fomes Laricis	48	....	56	35	9
Echinodontium tinctorium	8	....	....	75	25
Poria subincarnata	4	....	....	....	100
Peniophora luna	3	....	100	....	....
Polyporus fibrillosus	2	....	....	50	50
Stereum sanguinolentum	2	....	....	100	....
Omphalia campanella	1	....	100	....	....
Unknown	18	....	33	45	22
Sap Rots—					
Polyporus abietinus } *Polyporus volvatus* }	6	....	100	....	....
Mixed Decay	97	23	25	16	36
Total	1,414				

As might be expected the great majority of the infections resulting from fungi which cause root and butt rots had entered the trees through the roots, though it was not uncommon for these fungi to enter through basal scars. In three instances *Polyporus Schweinitzii* had caused extensive decay in the upper portion of trees with dead tops, quite independent of any basal infections.

Roots served as avenues of entrance for 56 per cent of the infections by *Lentinus Kauffmanii* (brown pocket rot). Since this fungus frequently causes a root and butt rot, it was thought that it might occur in patches, the causal fungus spreading in the ground or by root contact under the ground. However, in this study it was common to find infections associated with scars, branch stubs, and dead tops, which showed clearly that diseased trees may occur singly, having become infected by air-borne spores.

In considering *Fomes Pini* (red ring rot) it was apparent that 89 per cent of the infections by this fungus had entered the trees through branch stubs. Scars were not of importance as infection courts for this disease. A majority of

the scars examined in this work would be classified as scars caused by falling trees. In these instances the bark was bruised, exposing the sapwood. It appears that exposed heartwood is required for infection by this fungus.

It should be mentioned that scars were the most frequent infection courts for the important brown trunk rots (*Fomes pinicola, Trametes serialis, Poria microspora, Polyporus sulphureus*, and *Fomes Laricis*.) These scars were common in the basal logs of the trees which on manufacture would produce lumber of the best quality (plate IX, figure 1). For this reason the brown trunk rots were more evident that red ring rot in Grade 1 and Grade 2 logs.

Invariably the sap rots were associated with recent scars caused by falling trees.

RELATIVE IMPORTANCE OF THE MAJOR FUNGI CAUSING DECAY

On a Basis of Gross Merchantable Volume

The gross volume from stump height to a 12-inch top of the 1,977 trees analysed during this study amounted to 13,968,223 board feet. A total of 11·5 per cent of this volume was lost through decay (table 4). Red ring rot (*Fomes Pini*) far exceeded any other decay in volume of wood destroyed (4·6 per cent).

TABLE 4—RELATIVE IMPORTANCE OF THE MAJOR FUNGI CAUSING DECAY IN SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS
(Basis 1,977 trees)

ORGANISM	Volume of Rots in: Grade 1 Logs — Total volume Grade 1 5,119,267 bd. ft.		Grade 2 Logs — Total volume Grade 2 5,094,408 bd. ft.		Grade 3 Logs — Total volume Grade 3 3,754,548 bd. ft.		Gross Merchantable Volume (All Logs) — Total volume 13,968,223 bd. ft.	
	Bd. ft.	Percentage of total volume Grade 1	Bd. ft.	Percentage of total volume Grade 2	Bd. ft.	Percentage of total volume Grade 3	Bd. ft.	Percentage of total volume All logs
Root and Butt Rots—								
Polyporus Schweinitzii	142,321	2·8	70,484	1·4	59,312	1·6	272,117	1·9
Poria subacida and Poria colorea.	29,878	0·6	6,111	0·1	....	....	35,989	0·3
Others	7,118	0·2	3,372	0·1	325	trace*	10,815	0·1
Unknown	4,489	0·1	751	trace	781	trace	6,021	trace
Brown Pocket Rot—								
Lentinus Kauffmanii	83,481	1·6	31,210	0·6	14,926	0·4	129,617	0·9
White Trunk Rot—								
Fomes Pini	29,289	0·6	113,996	2·2	495,855	13·2	639,140	4·6
Brown Trunk Rots—								
Fomes pinicola	35,308	0·7	63,133	1·2	112,526	3·0	210,967	1·5
Trametes serialis and Poria microspora.	10,965	0·2	27,601	0·5	56,721	1·5	95,287	0·7
Polyporus sulphureus	8,641	0·2	19,120	0·4	48,736	1·3	76,497	0·6
Fomes Laricis	8,979	0·2	12,109	0·2	43,502	1·2	64,590	0·5
Others	....	....	....	....	8,637	0·2	8,637	0·1
Unknown	1,681	trace	5,432	0·1	3,347	0·1	10,460	0·1
Sap Rots—								
Polyporus abietinus and Polyporus volvatus.	350	trace	765	trace	644	trace	1,759	trace
Mixed Decay	5,526	0·1	6,752	0·1	34,803	0·9	47,081	0·3
Total	368,026	7·2	360,836	7·1	880,115	23·4	1,608,977	11·5

*Trace means that percentage of rot was less than 0.1.

Brown butt rot (*Polyporus Schweinitzii* ranked second in importance (1·9 per cent), followed by brown crumbly rot (*Fomes pinicola*) with 1·5 per cent. Each of the remaining fungi had destroyed less than 1·0 per cent of the total volume measured.

On a Basis of Grade 1 Logs

The total volume of the logs scaled as Grade 1 was 5,119,267 board feet or 37·0 per cent of the total volume measured. Decay had destroyed 7·2 per cent of this volume (table 4). This figure is appreciably less than the loss calculated on a basis of gross merchantable volume. Root and butt rots were responsible for a loss amounting to 3·7 per cent of the total volume Grade 1. A major portion of this wood was destroyed by *Polyporus Schweinitzii.* Brown pocket rot (*Lentinus Kauffmanii*) was next in importance, affecting 1·6 per cent of the total volume Grade 1. In considering red ring rot (*Fomes Pini*) it was evident that this decay was of minor importance in Grade 1 material, having destroyed only 0·6 per cent of the total volume Grade 1. The accumulated loss from the brown trunk rots was considerably higher (1·5 per cent of the total volume Grade 1) than that for red ring rot, presumably because of the ability of the causal fungi of these decays to infect the trees through wounds made by falling trees as was described previously. *Fomes pinicola* was the most important brown trunk rot in Grade 1 logs.

On a Basis of Grade 2 Logs

The total volume of the logs scaled as Grade 2 was 5,094,408 board feet or 36·0 per cent of the total. Decay had destroyed 7·1 per cent of this volume (table 4), and, as in Grade 1 logs, this figure is considerably lower than the loss calculated on a basis of gross merchantable volume. It is of interest to note the similarity of the total and decay volumes of Grade 1 and Grade 2 logs. A majority of the volume Grade 2 occurred in the second and third logs of trees. Therefore, the decays which occur most frequently in the basal portion of the trees (root and butt rots and brown pocket rot) are of little importance in logs of this grade while the trunk rots, which result largely from fungi that enter the trees through branches and scars, are more significant.

On a Basis of Grade 3 Logs

The total scale of the Grade 3 logs was 3,754,548 board feet or 27·0 per cent of the total volume measured. Over 23·0 per cent of this volume was lost through decay (table 4). This figure is much higher than the percentage loss expressed on the basis of gross merchantable volume. A major part of the decay in Grade 3 logs (20·5 per cent of the total volume Grade 3) was caused by the trunk rots. Over 13·0 per cent of the loss was due to red ring rot It is of interest to mention that 1·6 per cent of the wood in Grade 3 logs was destroyed by *Polyporus Schweinitzii,* the fungus causing brown butt rot. In these instances the fungus had entered the trees through dead tops.

From the above remarks it is evident that the percentage loss from decay in Grade 1 and Grade 2 logs was considerably less than the figure calculated on a basis of gross merchantable volume. This indicates that a major part of the decay in mature and overmature stands of Sitka spruce on the better sites is located in the upper part of the trunks. Such material, because of branches and other visible defects, would be classified as Grade 3 or culls, and hardly suitable for the recovery of lumber. The greater incidence of decay in the tops of older trees creates a problem for consideration before altering logging methods to include the closer utilization of this material.

The root and butt rots and brown pocket rot accounted for most of the defect in Grade 1 logs. Brown pocket rot did not prove serious on the areas investigated. However, most of this decay occurred in basal logs of the finest quality. Although red ring rot caused the greatest volume of decay the results suggest that this rot usually is not present in the basal logs of infected trees. Of the trunk rots it was apparent that the brown trunk rots were of the greater importance in Grade 1 logs.

In most instances the wood-destroying fungi which occur in living trees are not of importance as agents of decay of wood in service. However, among the brown trunk rots in Sitka spruce are included such fungi as *Trametes serialis* and *Poria microspora*, which for some time have been recognized as important finest quality. Although red ring rot caused the greatest volume of decay the commonly present in Grade 1 logs, which are the most suitable for the recovery of clear lumber (plate IX). The incipient stages of these decays are difficult to detect, and previous investigations have demonstrated that the causal fungi may revive in infected wood after a long period of dormancy. For these reasons it is possible that the early decay may be overlooked at the mill when infected logs are sawn, and the fungi may destroy the lumber at a later date. It is suggested that this explains in part the frequent occurrence of dry rot in air-seasoned lumber of Sitka spruce.

With the exception of brown pocket rot the major decays of Sitka spruce have been described in detail in the publication which have been mentioned under the heading of "Review of Previous Investigations". Under these circumstances it appears unnecessary to repeat these descriptions at this time. Since brown pocket rot has not been described previously it seems desirable to discuss this disease in some detail.

BROWN POCKET ROT OF SITKA SPRUCE

Occurrence of the Disease

During the course of this investigation brown pocket rot was found to be generally distributed on the Queen Charlotte Islands. Cultures of the causal fungus have been isolated from infected trees occurring in Washington and Oregon and Dr. A. H. Smith has reported in correspondence that sporophores identical with those produced by the fungus causing brown pocket rot have been collected from logs of Sitka spruce in California. It appears, therefore, that the fungus has a wide distribution, which coincides with the range of Sitka spruce.

The disease occurred on all sites investigated. The analysis of infected trees demonstrated that the rot was more extensive in the roots and basal regions than at some distance up the trunks (plate III). This suggests that the disease is predominantly a root and butt rot which later develops into a trunk rot.

The Decay

The decay is a brown pocket rot or pocket dry rot which occurs in the heartwood of living Sitka spruce. The fungus may cause a butt, trunk, or top rot. It occurs most frequently as a butt rot, confined to the first and second 40-foot logs, with an occasional basal infection extending into the third log (plates III and IV). Given sufficient moisture, the fungus may continue to develop in dead trees for long periods. Sporophores of the associated fungus were collected on infected trees which are known to have been felled more than 50 years ago (plate V, figure 2).

The individual pockets are elongated in the direction of the grain, with rounded to somewhat pointed ends. A sharp line of demarcation exists between the sound and decayed wood (plates III and IV). In the final stages the pockets may become so numerous that they unite into a solid mass of rot. It is common to find isolated pockets at some distance from the main body of decay and separated from it by what appears to be sound wood. For this reason the amount of rot visible on the two ends of a log may not indicate the extent of internal decay. The difficulty in estimating for brown pocket rot has resulted in scalers culling most logs with this decay.

A brownish stain develops in the wood of pockets with incipient decay. Later the pockets become filled with a brown, crumbly mass which tends to form cubes. Frequently plates of white mycelium occur in the decayed wood

The Causal Fungus

Small agarics were found associated with pocket rot in recently-felled trees. On the end section of a log the sporophores developed at the margin of pockets containing advanced decay (plate V, figure 1). Fruiting bodies occurred in abundance in the exposed pockets of old logs (plate V, figure 2). In culture the fungous growth was the same when the fungus was isolated from infected wood as when it was derived from the context or spores of the fruiting bodies.

Specimens of the sporophores were sent to Dr. Alexander H. Smith who considered it to be an undescribed species. He named it *Lentinus Kauffmanii* and prepared the description given in (2).

In this study an abundance of sporophores was found during the months of May, June, September, and October. Invariably they developed from the wood at the margin of pockets which had become exposed to the atmosphere. The stumps, roots, and ground surrounding the bases of infected trees were examined carefully for the presence of fruiting bodies, but in no instance were they found.

External Indications of the Disease

In some instances the fungi causing decay in living trees produce conks on the outside which serve as an external indication of disease. Apparently fruiting bodies of the fungus causing brown pocket rot are produced entirely on infected wood which has become exposed to the atmosphere (plate V). For this reason it is improbable that they would occur on the bark of, or on the ground adjacent to, infected trees, and in this way serve as an external indication of decay in standing timber. Further, it is evident that the sporophores are small and difficult to distinguish from the many other mushrooms which occur commonly in the forests. To date no reliable external indication is known which would indicate the presence of this decay in standing trees. A majority of the infections by brown pocket rot had occurred through the roots and were present in trees more than 300 years of age. Younger trees became diseased as the result of wound infections (plate IV, figure 2).

Analysis of trees with basal infections indicated that when a large area of rot occurred on the stump end of the basal, 40-foot log, the decay extended into the second log (plate III). Infections with a small number of isolated pockets at the base usually did not reach the top of the first log (plate IV, figure 1).

THE SIGNIFICANCE OF RED RING ROT IN SITKA SPRUCE

On a Basis of All Trees Infected by *Fomes Pini*

In a preceding section it was demonstrated that red ring rot appeared to be of minor importance in Grade 1 logs, when the volume decayed was expressed as a percentage of the total Grade 1 recovered from the 1,977 trees analysed during this study. It is of interest to ascertain the importance of the decay in the 354 trees which were infected with this disease. The percentage volume by grade which was free from red ring rot in diseased trees of different age classes is given in table 5. It is evident that 97·8 per cent of the Grade 1 and 89·2 per cent of the Grade 2 wood in trees infected by this rot is free from this decay. Heavy loss occurs in the Grade 3 logs since only 55·4 per cent of this material is free from red ring rot. This percentage of the average volumes Grade 1 free from this rot is similar for trees in all age classes. In general, this also applies to the Grade 2 and Grade 3 logs.

TABLE 5—IMPORTANCE OF THE DECAY CAUSED BY *Fomes Pini* IN SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

(Basis 354 diseased trees)

AGE	No. of Trees	Grade 1 Logs		Grade 2 Logs		Grade 3 Logs		Gross Merchantable Volume (All Logs)	
		Average Volume	Free from rot	Average Volume	Free from rot	Average Volume	Free from rot	Average Volume	Free from rot
		bd. ft.	%	bd. ft.	%	bd. ft.	%	bd. ft.	%
200.........	1	....	....	268	66·8	63	0·0	331	54·1
250.........	9	1,807	100·0	1,408	68·3	1,110	32·2	4,325	72·3
300.........	32	920	94·5	2,081	87·2	1,674	62·4	4,675	79·8
350.........	24	2,490	97·6	2,497	88·1	2,785	61·2	7,772	81·5
400.........	77	3,544	99·3	2,368	90·6	2,896	56·2	8,809	82·8
450.........	46	3,458	96·0	3,512	85·4	3,063	44·2	10,033	76·5
500.........	98	4,780	97·8	3,079	89·2	3,803	57·3	11,662	82·3
550.........	42	5,615	97·1	4,097	93·4	3,494	57·8	13,206	85·5
600.........	15	5,224	98·6	4,667	93·9	4,601	54·1	14,492	83·0
650.........	5	5,249	100·0	7,593	81·4	6,682	54·3	19,524	77·1
700.........	4	4,826	97·6	2,356	100·0	3,958	68·2	11,139	87·7
750.........	1	....	....	2,537	100·0	2,698	0·0	5,235	48·5
Total or Average..	354	3,834	97·8	3,033	89·2	3,198	55·4	10,066	81·8

On a Basis of Trees with Conks which Extend into the Basal Portion of the Trunks

In many of the diseased trees considered in table 5, the sporophores were located on the trunks at a considerable distance above the ground level. The true significance of the disease may be ascertained by determining the amount of decay in trees which have long columns of rot, and fruiting bodies which extend down into the basal portion of the trunks (plate VI, figure 1). An analysis of these trees is given in table 6.

TABLE 6—IMPORTANCE OF RED RING ROT IN DISEASED TREES WHICH HAVE VISIBLE SPOROPHORES

(1) Above and on the second 40-ft log.
(2) Above and on the basal 40-ft log.

Location of Conks	No. of trees	Grade 1 Logs			Grade 2 Logs			Grade 3 Logs			Gross Merchantable Volume (All Logs)		
		Average volume	Free from		Average volume	Free from		Average volume	Free from		Average volume	Free from	
			Red ring rot	All rots		Red ring rot	All rots		Red ring rot	All rots		Red ring rot	All rots
		bd. ft.	%	%	bd. ft.	%	%	bd. ft.	%	%	bd. ft.	%	%
Above and on the second 40-ft. log	129	2,994	97·7	92·7	2,585	81·1	75·2	3,204	42·5	36·6	8,783	72·7	67·0
Above and on the basal 40-ft. log	18	2,482	69·8	57·7	2,702	61·4	47·5	4,822	48·9	46·7	10,005	57·5	49·7
Total or Average	147	2,932	94·8	89·1	2,599	78·6	71·6	3,402	43·6	38·3	8,933	70·6	64·7

It is evident that in instances where the rot column and conks extend into that part of the tree which would constitute the second log, an average of 97·7 per cent of the volume Grade 1 and 81·1 per cent of the volume Grade 2 was free from this decay. Further, 92·7 of the volume Grade 1 and 75·2 per cent of the volume Grade 2 was comprised of sound wood not affected by any form of decay. A considerable recovery of sound wood of the better grades was obtained in instances where the sporophores extended to a distance of less than 40 feet above the ground in infected trees. However, in some cases an additional loss from butt rot gave a total deduction which would necessitate culling the logs.

The Utilization of Trees Infected with Red Ring Rot

Sporophores serve as a reliable external indication of this type of decay in Sitka spruce. Although the decay may be extensive in the tops of trees, usually it does not extend for any appreciable distance below the lowermost conk which is present on an infected tree. Diseased trees with long columns of fruiting bodies which extend down to a distance of 50 to 60 feet above the ground should be felled, since it is probable that a high percentage of the Grade 1 or Grade 2 wood in the basal log will be free from this decay. This principle is illustrated in figure 2, which gives a diagrammatic representation of two trees analyzed during this study. Tree "A" with no external indication of decay was felled and yielded four Grade 2 and Grade 3 logs, with a total volume of 6,855 board feet. Tree "B" may be considered typical of the diseased trees which were left on some areas selectively logged because of external indications of decay. An analysis of Tree "B" shows that the basal, 40-foot log is sound and has a volume of 6,910 board feet, which is greater than the total of the four logs recovered from Tree "A". The basal log in Tree "B" is Grade 1 in quality and has a much greater value than the logs in Tree "A".

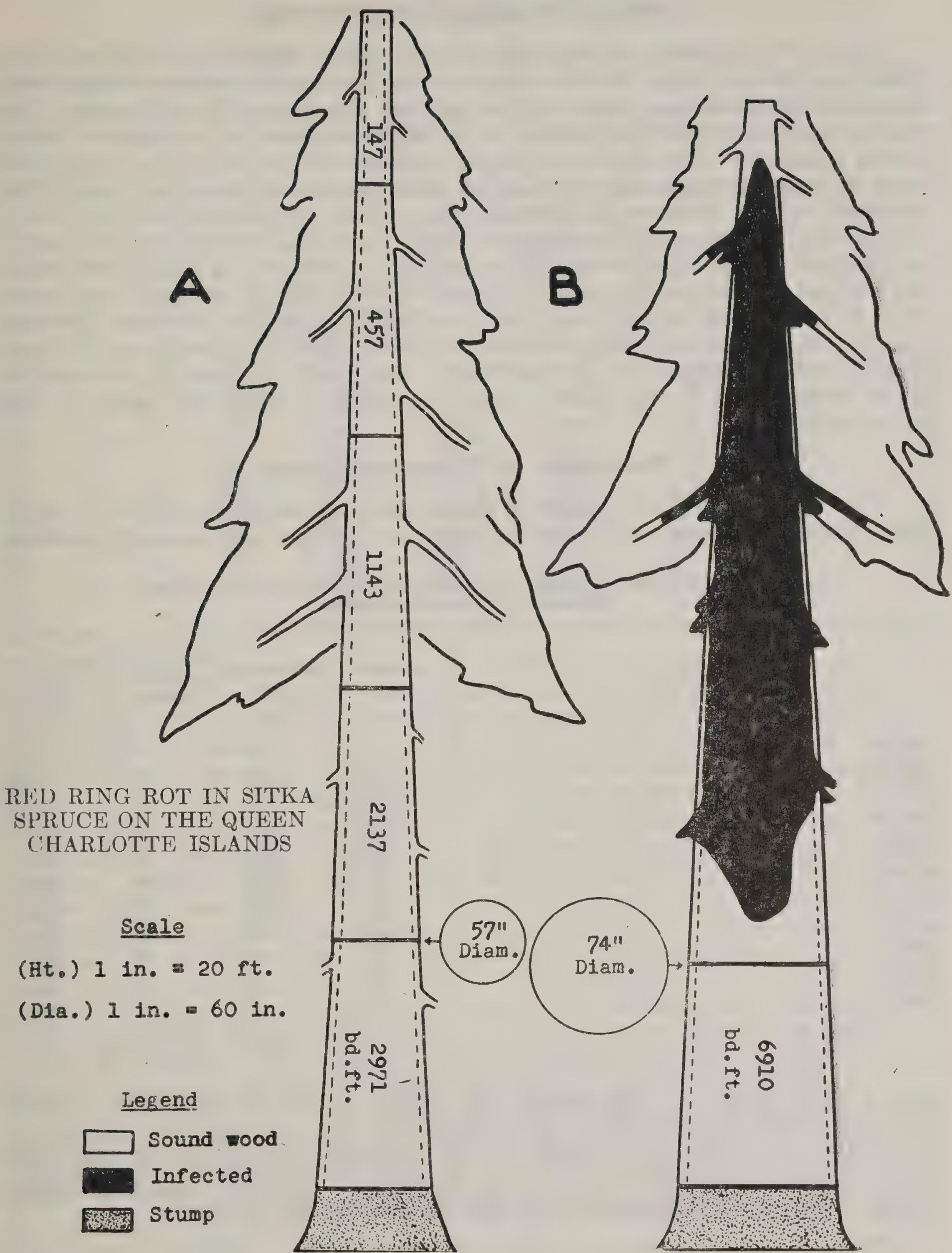

A
B
147
457
1143
2137
2971
bd.ft.
57"
Diam.
74"
Diam.
6910
bd.ft.
RED RING ROT IN SITKA
SPRUCE ON THE QUEEN
CHARLOTTE ISLANDS
Scale
(Ht.) 1 in. = 20 ft.
(Dia.) 1 in. = 60 in.
Legend
Sound wood
Infected
Stump

Figure 2.

DECAY IN RELATION TO AGE

It is of importance to mention that the data presented for trees in the older age classes apply to the residuals in overmature stands, which were considered of economic value under present standards of utilization. The results, therefore, would be applicable to the living trees in overmature forests of this character. The relation of decay to crop rotation and other considerations in forest management requires the investigation of the stand rather than individual trees. Because of mortality losses from suppression, disease, windthrow, and other causes, the culmination of net growth of the stand will occur before that of individual trees. The abundance of snags and large trees, windthrown and broken as the result of decay, showed that in the past there were more trees per acre which would have yielded a larger net volume than was obtained at the present time. In the overmature forests investigated it would appear that the principle of the survival of the fittest has been in progress for many years, and it was these survivors which formed the basis of this investigation.

Percentage of Trees with Decay

The increase in the incidence of decay with age is given in table 7. On a basis of the trees analysed it is evident that on the slope and bench types Sitka

TABLE 7—RELATION BETWEEN AGE AND INCIDENCE OF DECAY IN SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

Age Class	Average age	Number of trees	Number of trees with decay	Trees with decay %
26– 75	70	8	0	0
76–125	95	22	0	0
126–175	149	106	7	6·6
176–225	199	99	12	12·1
226–275	254	159	37	23·3
276–325	299	277	73	26·4
326–375	349	198	78	39·4
376–425	401	290	164	56·6
426–475	454	196	124	63·3
476–525	500	399	263	65·9
526–575	539	135	97	71·9
576–625	597	44	36	81·8
626–675	650	17	15	88·2
676–725	698	23	23	100·0
726–775	744	4	4	100·0
Total or Average	386	1,977	933	47·2

spruce may attain a considerable age before decay is commonly present. Infections were not common in trees under 200 years of age. The percentage of diseased trees increased steadily in the later age classes, and at 700 years of age all the trees were infected at some point in their merchantable length. Of the 1,977 trees analysed 47·0 per cent had deductions for decay.

Percentage in Merchantable Volume

Data on the average gross merchantable volume, decay volume, and net merchantable volume by age classes are given in table 8 and figure 3. In figure

TABLE 8—RELATION BETWEEN AGE AND NET MERCHANTABLE VOLUME AND NET PERIODIC INCREMENT IN 1,977 SITKA SPRUCE TREES ON THE QUEEN CHARLOTTE ISLANDS

(Curved Values)

Age	No. of trees	Average gross merchant-able volume	Average gross periodic increment	Average volume of decay	Decay	Average net merchant-able volume	Average net periodic increment
		bd. ft.	bd. ft.	bd. ft.	%	bd. ft.	bd. ft.
50	8	200	....	0	0	200	....
100	22	850	650	0	0	850	650
150	106	1,750	900	0	0	1,750	900
200	99	2,750	1,000	20	0·7	2,730	980
250	159	3,850	1,100	100	2·6	3,750	1,020
300	277	5,000	1,150	250	5·0	4,750	1,000
350	198	6,150	1,150	450	7·3	5,700	950
400	290	7,300	1,150	700	9·6	6,600	900
450	196	8,450	1,150	1,000	11·8	7,450	850
500	399	9,600	1,150	1,375	14·3	8,225	775
550	135	10,700	1,100	1,775	16·6	8,925	700
600	44	11,800	1,100	2,225	18·9	9,575	650
650	17	12,900	1,100	2,725	21·1	10,175	600
700	23	13,850	950	3,275	23·6	10,575	400
750	4	14,500	650	3,850	26·6	10,650	75

3 the top curve represents the average gross merchantable volume, the lower curve the average decay volume per tree, and the middle curve the average net volume after making the deduction for decay. It is evident that the gross merchantable volume of Sitka spruce trees continues to increase at a more or less uniform rate until an advanced age is reached (650 years). The average gross merchantable increment amounted to 650 board feet in trees for the period from 50 to 100 years of age. This periodic increment increased to 1,150 board feet in trees from 250 to 300 years of age, and then remained constant until the trees reached 500 years of age (table 8). The average decay volume was very small in trees up to 200 years of age, amounting to less than 1·0 per cent of the gross merchantable volume. The amount of decay increased in the subsequent age classes until in 750-year-old trees 26·6 per cent of the gross merchantable volume was destroyed. The increase in the amount of decay with age is of importance in diminishing the net merchantable volume and net periodic increment. It is evident from table 8 that the maximum, average, net periodic increment occurs in trees from 250 to 300 years of age. This figure becomes progressively less in older trees.

It is evident, then, that decay increases with age in Sitka spruce on the Queen Charlotte Islands. If the trees occurred in even-aged stands there would be no difficulty in determining the age of the stand and applying a factor to cover the losses from decay. However, the stands investigated were uneven-aged with one or two predominant age classes. It appears difficult to apply an age-decay factor to uneven-aged stands, since it would be necessary to determine the ages of the individual trees. Because of the predominance of one or two age classes in all stands investigated, it was felt that with some experience it would be feasible to place the trees into broad age classes on the basis of the size of the trees, appearance of the bark, and form of the crown. With such a procedure the factor for decay would vary in accordance with the age classes which occurred in the stand. This method should result in a more accurate estimation of the current and future losses from decay than methods which disregard the factor of tree ages in uneven-aged stands of this character.

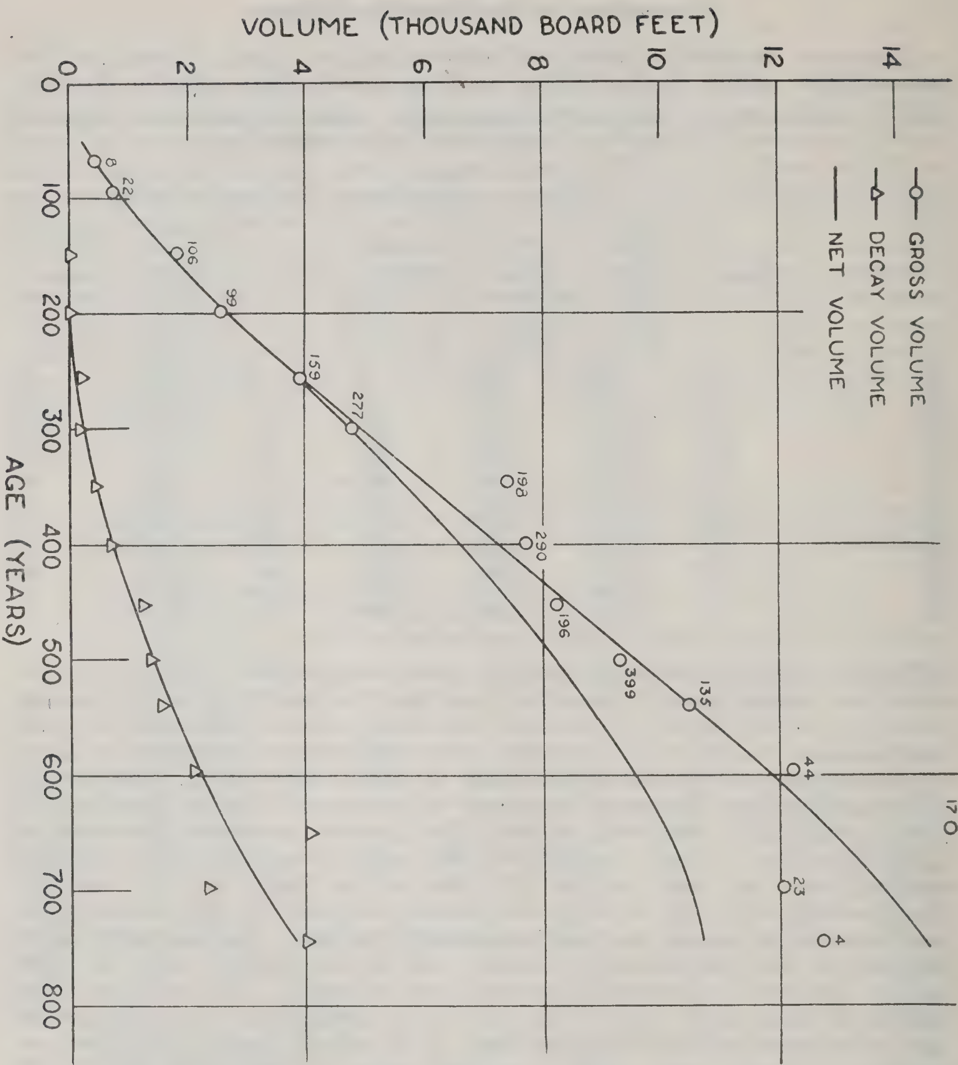


Figure 3.—Relation between Age and Gross Merchantable Volume, Decay Volume, and Net Merchantable Volume in Sitka Spruce on the Queen Charlotte Islands.

DECAY IN RELATION TO RATE OF GROWTH

The relation between rate of growth or vigour and amount of decay appears to be a controversial subject among foresters and loggers. Some believe that vigorous, fast-growing trees are less subject to decay than the more suppressed or slow-growing individuals in the stand. To provide information on this subject for Sitka spruce the trees analysed in this study were divided into two groups, using the same method as employed by McCallum (14) for balsam fir in Eastern Canada. The gross merchantable volume of each tree was compared with the average gross merchantable volume for trees of the same age as indicated on the age-gross merchantable volume curve given in figure 3. If the gross merchantable volume of a tree was greater than the curved value the tree was placed in the fast-growing group. If less, the tree was placed in the slow-growing group. The results of this analysis are given in table 9.

Table 9—Comparison of the Amount of Decay in Fast- and Slow-growing Sitka Spruce on the Queen Charlotte Islands

Age class	Number of trees		Average gross merchantable volume		Average volume of decay		Decay %	
	Fast growing	Slow growing	Fast growing	Slow growing	Fast growing	Slow growing	Fast growing	Slow growing
			bd. ft.	bd. ft.	bd. ft.	bd. ft.		
26– 75	10	5	840	330	0	0	0·0	0·0
76–125	11	11	1,116	423	0	0	0·0	0·0
126–175	46	60	2,849	1,006	17	3	0·6	0·3
176–225	25	64	6,582	1,351	45	17	0·7	1·2
226–275	65	94	7,086	1,751	408	79	5·8	4·5
276–325	107	170	8,189	2,633	289	127	3·5	4·8
326–375	108	90	10,486	3,631	642	196	6·1	5·4
376–425	128	162	11,851	4,387	916	511	7·7	11·7
426–475	70	126	14,729	4,623	2,419	618	16·4	13·4
476–525	153	249	15,171	5,709	2,633	925	17·4	10·1
526–575	58	77	15,853	6,410	2,456	843	15·5	13·1
576–625	19	25	18,606	7,339	3,001	1,488	16·1	20·3
626–675	10	7	21,109	6,053	5,878	1,543	27·8	25·6
676–725	7	16	21,161	8,003	3,177	1,951	15·0	24·4
726–775	1	3	21,409	9,795	5,322	3,563	24·9	36·4
Total or Average	818	1,159	11,371	4,026	1,350	436	11·8	10·8

In all age classes the average gross merchantable volume of the fast-growing trees was considerably greater than that for the slow-growing trees. The average gross merchantable volume for all fast-growing trees amounted to 11,371 board feet. For the slow-growing trees this figure was 4,026 board feet. The average volume of decay was greater for the fast-growing trees in all age classes in which decay was present. However, on a basis of percentage of decay it was apparent that there was no consistent difference between the fast- and slow-growing trees in the different age classes. The average percentage of decay for all fast-growing trees amounted to 11·8 per cent and for the slow-growing trees 10·8 per cent.

DIAMETER RELATIONSHIPS

Decay in Relation to Diameter

As was mentioned previously, Sitka spruce on the Queen Charlotte Islands occurs in uneven-aged stands in mixture with western hemlock and western red cedar. The results of this study do not provide foresters with information which would assist in estimating ages in order to obtain age-decay deductions for the individual trees. For this reason a correlation between diameter and decay should prove to be of value. The diameter used in this work was not fixed at any specific stump height but was taken at the point where it would be practical to cut the trees. This conforms with the standard practice for cruising in big timber which usually has a large butt swell.

During this investigation it was apparent that except for red ring rot a greater part of the decay in Sitka spruce would be classified as hidden defect, which could not be ascertained by the presence of sporophores or other external indications. Therefore, it is not feasible to estimate with any degree of accuracy the amount of decay in individual trees. It has been shown that the amount of decay increases with age and from table 10 it is evident that on a basis

Table 10—Relation Between Diameter (at which the trees were cut) and Net Merchantable Volume in 1,977 Sitka Spruce Trees on the Queen Charlotte Islands

(Curved Values)

Diameter	No. of trees	Average age	Average gross merchantable volume	Average volume of decay	Decay %	Average net merchantable volume
			bd. ft.	bd. ft.	%	bd. ft.
20	37	202	450	0	0·0	450
25	74	240	700	0	0·0	700
30	114	265	1,100	25	2·3	1,075
35	153	294	2,000	100	5·0	1,900
40	193	350	2,950	200	6·8	2,750
45	198	375	4,025	325	8·1	3,700
50	231	392	5,225	450	8·6	4,775
55	206	409	6,600	600	9·1	6,000
60	223	416	8,200	775	9·5	7,425
65	160	441	10,150	1,025	10·0	9,125
70	152	448	12,200	1,400	11·5	10,800
75	94	480	14,250	1,950	13·7	12,300
80	68	481	17,050	2,525	14·8	14,525
85	27	513	19,925	3,250	16·3	16,675
90	29	516	22,850	4,075	17·8	18,775
95	12	479	25,900	5,225	20·2	20,675
100	6	534	29,150	6,950	23·8	22,200

of average figures both age and decay increase with increasing diameter. This would suggest that a more accurate estimate of the amount of decay in stands of Sitka spruce might be obtained by applying a defect factor to trees in each of the different diameter classes.

The relation between diameter and decay for Sitka spruce in this study is given in table 10. It was evident that decay was not of importance in the trees included in the 20- and 25-inch diameter classes. The average percentage of decay increased in trees of the larger diameters until approximately 24·0 per cent of the volume was lost in the 100-inch diameter class. Curves illustrating the relation between diameter and volume of gross merchantable timber, decay, and net merchantable timber are given in figure 4.

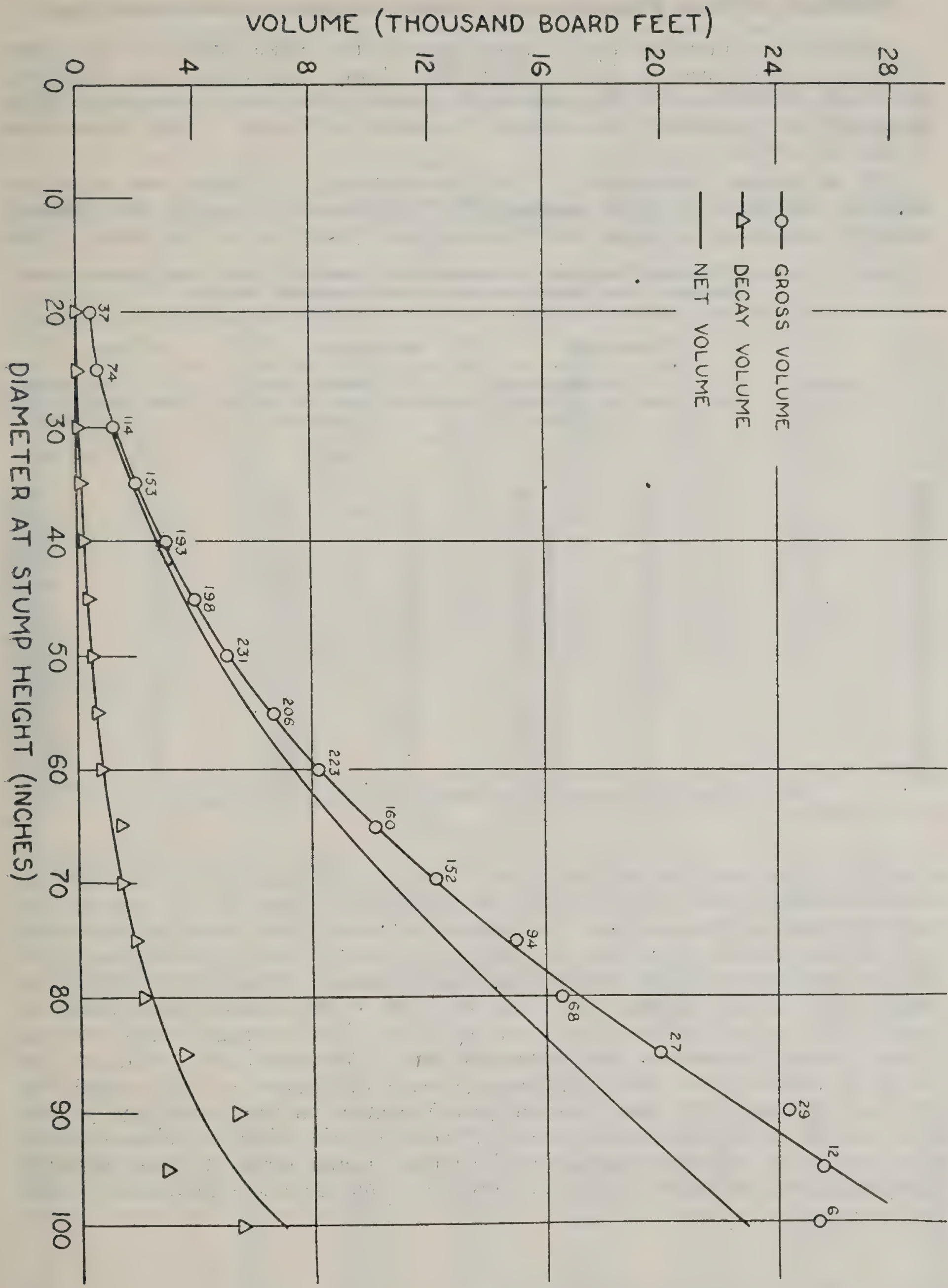


Figure 4.—Relation between Diameter and Gross Merchantable Volume, Decay Volume, and Net Merchantable Volume in Sitka Spruce on the Queen Charlotte Islands.

Relation Between Diameter and Volume by Grade and Forest Type

During this investigation it was observed that Sitka spruce of the slope type appeared to occur in denser stands than those of the bench type. Further, the trunks of the trees of the slope type seemed to be freer of branches. This indicated the possibility of a greater recovery of Grade 1 logs from trees of the slope type.

It is evident from table 11, that no consistent difference was apparent between the average gross merchantable volumes of trees in the different diameter classes in the slope and bench types. Therefore, on the basis of this

Table 11—Relation Between Diameter (at which trees were cut) and Gross Merchantable Volume in Sitka Spruce on the Queen Charlotte Islands

Diameter	Slope type		Bench type		All types	
	No. of trees	Average gross merchantable volume	No. of trees	Average gross merchantable volume	No. of trees	Average gross merchantable volume
		bd. ft.		bd. ft.		bd. ft.
20	13	445	24	434	37	438
25	17	646	57	727	74	709
30	35	1,149	79	1,193	114	1,179
35	49	2,050	104	1,956	153	1,986
40	67	3,203	126	2,899	193	3,004
45	69	4,154	129	3,924	198	4,004
50	87	5,286	144	4,972	229	5,091
55	68	6,962	138	6,582	206	6,707
60	82	8,228	141	8,145	223	8,176
65	64	9,936	96	10,293	160	10,151
70	44	11,939	108	12,334	152	12,220
75	37	15,311	57	14,689	94	14,933
80	24	16,614	44	16,373	68	16,458
85	3	19,302	24	20,041	27	19,959
90	4	24,630	25	24,277	29	24,326
95	3	20,854	9	27,089	12	25,530
100	1	22,668	5	26,032	6	25,471
Total or Average	667	6,949	1,310	7,125	1,977	7,065

study the gross merchantable volumes of trees of both types may be regarded as one sample. The average gross merchantable volume of all trees of the slope type was 6,949 board feet. For trees of the bench type this figure amounted to 7,125 board feet. However, on a basis of grade it was apparent that trees of the slope type yielded considerably more Grade 1 wood than trees of the bench type (tables 12 and 13). This may be of importance when grade or quality of the logs is taken into consideration. The average volume of the Grade 1 wood in trees of the slope type was 3,252 board feet, while on the bench type this figure was 2,252 board feet, a difference of 1,000 board feet per tree. In each type there was no great variation in the percentages of the gross merchantable volumes in Grade 1 wood for the diameter classes above 40 inches. The average volumes of the Grade 1 and Grade 2 wood together when expressed as percentages of the gross merchantable volumes were similar for trees on both types.

TABLE 12—RELATION BETWEEN DIAMETER (AT WHICH TREES WERE CUT) AND GROSS MERCHANTABLE VOLUME BY GRADE IN SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

(Slope type)

Diameter	No. of trees	Grade 1 Logs		Grade 1 and 2 Logs		Grade 3 Logs	
		Average volume	Expressed as percentage of gross merchant-able volume	Average volume	Expressed as percentage of gross merchant-able volume	Average volume	Expressed as percentage of gross merchant-able volume
		bd. ft.		bd. ft.		bd. ft.	
20	13	....	0·0	269	60·4	176	39·6
25	17	....	0·0	408	63·3	237	36·7
30	35	25	2·2	835	72·6	314	27·4
35	49	404	19·7	1,517	74·0	533	26·0
40	67	1,268	39·6	2,564	80·1	639	19·9
45	69	1,958	47·1	3,307	79·6	847	20·4
50	87	2,399	45·4	4,195	79·4	1,092	20·6
55	68	3,258	46·8	5,385	77·4	1,577	22·6
60	82	4,432	53·9	6,623	80·5	1,605	19·5
65	64	4,648	46·8	7,224	72·7	2,712	27·3
70	44	5,509	46·1	9,071	76·0	2,868	24·0
75	37	7,389	48·3	11,254	73·5	4,057	26·5
80	24	8,827	53·1	12,463	75·0	4,151	25·0
85	3	11,990	61·8	15,751	81·6	3,551	18·4
90	4	9,392	38·1	14,547	59·1	10,083	40·9
95	3	9,392	45·0	15,274	73·2	5,580	26·8
100	1	7,926	35·0	19,882	87·7	2,786	12·3
Total or Average	667	3,252	46·8	5,302	76·3	1,647	23·7

TABLE 13—RELATION BETWEEN DIAMETER (AT WHICH THE TREES WERE CUT) AND GROSS MERCHANTABLE VOLUME BY GRADE IN SITKA SPRUCE ON THE QUEEN CHARLOTTE ISLANDS

(Bench Type)

Diameter	No. of trees	Grade 1 Logs		Grade 1 and 2 Logs		Grade 3 Logs	
		Average volume	Expressed as percentage of gross merchant-able volume	Average volume	Expressed as percentage of gross merchant-able volume	Average volume	Expressed as percentage of gross merchant-able volume
		bd. ft.		bd. ft.		bd. ft.	
20	24	....	0·0	292	67·3	142	32·7
25	57	....	0·0	497	68·3	230	31·7
30	79	33	2·8	875	73·4	318	26·6
35	104	451	23·0	1,406	71·9	550	28·1
40	126	762	26·3	2,129	73·4	770	26·6
45	129	1,234	31·4	2,894	73·8	1,030	26·2
50	144	1,628	32·7	3,689	74·2	1,282	25·8
55	138	2,166	32·9	4,828	73·4	1,754	26·6
60	141	2,969	36·5	5,973	73·3	2,172	26·7
65	96	3,321	32·3	7,181	69·8	3,112	30·2
70	108	4,197	34·0	8,908	72·2	3,426	27·8
75	57	4,896	33·3	10,356	70·5	4,333	29·5
80	44	5,099	31·1	11,132	68·0	5,241	32·0
85	24	6,977	34·8	14,367	71·7	5,675	28·3
90	25	6,948	28·6	15,802	65·1	8,475	34·9
95	9	4,390	16·2	21,137	78·0	5,952	22·0
100	5	7,424	28·5	16,721	64·2	9,311	35·8
Total or Average	1,310	2,252	31·6	5,097	71·5	2,028	28·5

Percentage of Decay by Diameter Class, Grade, and Forest Type

The percentage of decay is for the graded logs recovered from trees in the different diameter classes on the slope and bench types given in table 14. It is evident that the data fail to provide conclusive evidence that

TABLE 14—PERCENTAGE OF DECAY BY DIAMETER CLASS, GRADE, AND FOREST TYPE

Diameter	Volume of decay expressed as a percentage of the gross merchantable volume							
	Grade 1 Logs		Grade 1 and 2 Logs		Grade 3 Logs		Gross merchantable volume All grades	
	Slope	Bench	Slope	Bench	Slope	Bench	Slope	Bench
20	....	....	....	1·8	....	2·1	....	1·9
25	....	....	0·9	2·4	....	2·4	0·6	2·4
30	....	....	0·7	0·8	1·4	9·2	0·9	3·0
35	1·1	3·3	0·4	3·9	5·6	10·9	1·8	5·9
40	3·1	2·5	2·3	3·1	16·0	14·8	5·0	6·2
45	3·5	4·9	3·7	4·5	20·1	19·4	7·1	8·4
50	3·3	6·3	4·1	5·0	20·2	19·8	7·5	8·8
55	6·4	4·7	4·9	7·5	24·1	14·5	9·3	9·4
60	4·8	5·9	6·4	5·1	28·9	16·7	10·8	8·2
65	11·9	6·5	11·9	6·0	35·3	22·8	18·3	11·1
70	5·7	6·1	5·2	7·6	33·9	22·5	12·1	11·8
75	5·4	8·3	6·8	8·9	25·2	25·8	11·7	13·9
80	12·1	9·5	9·7	8·3	23·4	25·9	13·1	14·0
85	1·2	11·6	3·6	12·4	84·4	29·5	18·5	17·3
90	3·8	15·9	8·9	15·0	50·4	33·0	25·9	21·3
95	22·5	16·1	13·9	9·6	8·6	18·9	12·5	11·7
100	....	31·7	....	24·1	50·0	25·6	6·1	24·6
Total or Average	6·7	7·6	6·4	7·5	27·4	21·8	11·4	11·5

appreciably more decay was present in trees of one type than the other. More decay occurred in trees of the smaller diameter classes on the bench type. This was accounted for by the greater incidence of root and butt rots in the smaller trees of that type. On a basis of gross merchantable volume, which includes logs of all grades, the average percentage of decay for all trees of the slope type amounted to 11·4. For the bench type this figure was 11·5 per cent. In both types the percentage of decay for Grade 1 logs and Grade 2 logs together was considerably less than that for the Grade 3 logs. Consideration should be given to this when recovery by grade is of importance.

DISCUSSION

The present study was undertaken primarily to provide information to timber cruisers, scalers, and operators which would assist in evaluating the importance of certain decays which had proved troublesome in overmature stands of Sitka spruce on the Queen Charlotte Islands. Discussion of the problem with representatives of the Forest Service and the logging industry, who over a period of years have acquired a general knowledge on the incidence and importance of decay, yielded many valuable suggestions based on observational evidence. An effort has been made to co-ordinate such information in this study and make it available generally to the Forest Service and the industry.

In some instance there has been a tendency to apply to Sitka spruce the information on particular rots which was obtained through years of experience in working with other West Coast species. It should be stressed that the effect of a wood-destroying fungus in Sitka spruce may be entirely different from that resulting when the same organism infects another species, such as Douglas fir or western

hemlock. Each tree species has to be treated individually in pathological investigations to ascertain the loss through decay. Further, the amount of decay in Sitka spruce in one region may differ from that in another region because of differences in environment. Under these circumstances it is not possible to apply the present results for Sitka spruce to areas other than the Queen Charlotte Islands.

As an initial step in determining the external indications of decay it was necessary to identify the various fungi causing rot in standing trees. It soon became evident that this problem was very complex and to date 31 different species of fungi have been found attacking the heartwood of living trees. Further, it was apparent that some of these fungi were unknown prior to this study. The present results indicate that except for red ring rot (*Fomes Pini*) there are no reliable, external indications of decay in overmature Sitka spruce. Consequently it is not possible for timber cruisers to estimate with accuracy the amount of decay in individual trees. However, as an alternative, it is possible in each region to determine the amount of decay in a sufficient number of felled and bucked trees of all ages and on all sites to serve as a sample of the condition of the timber. Such work would provide data in regard to the amount of decay which may be expected in uncut stands of a similar nature. It is felt that the present investigation provides this information for Sitka spruce of the slope and bench types which include the better individuals of this species on the Queen Charlotte Islands.

From the preceding paragraph it would appear that, if the loss through decay is to be expressed as a factor or percentage of the gross merchantable volume, there is little value in intensive investigations to determine the actual fungi which are involved in causing this decay. However, in some instances the damage from wood-destroying fungi extends beyond the loss arising from the destruction of wood in living trees. For example, the present work has shown that *Trametes serialis* and *Poria microspora,* which cause dry rot in Sitka spruce under service conditions occur commonly in living trees. The early stages of these decays are difficult to detect, and there seems little doubt that the frequent occurrences of dry rot in spruce lumber is the result of these decays escaping notice at the mill when infected logs are manufactured. It is evident, therefore, that considerable investigation of a fundamental nature is required to determine the characteristics of each fungus which causes rot in living trees. This is particularly true of the organisms that have not been recorded previously as wood-destroyers in living trees.

The problems which arise as the result of loss through decay are an important factor in formulating plans for the successful management of any forest. When, as in the present instance, the industry is operating in overmature timber, the importance of this work increases greatly. Young timber is usually relatively free from decay but as the age of the trees increases the loss from decay rises steadily. Finally a point is reached where the volume of decayed wood increases more rapidly than that of the sound wood and the trees suffer a mounting net loss year by year. In addition to this annual loss of sound wood it is evident also that the productive capacity of the area is considerably reduced. The results of this study indicate that on a basis of merchantable volume the maximum net periodic increment occurred in Sitka spruce from 250 to 300 years of age. The net periodic increment became progressively less for trees in the older age classes.

The present data demonstrate that in instances where grade of logs is of importance it may be misleading to state the loss through decay simply as a percentage of the gross merchantable volume. In operations where major emphasis is placed on cutting for the recovery of high-grade lumber, the loss

through decay should be expressed on a qualitative as well as quantitative basis. This analysis shows that the percentage of decay in Grade 1 (7·2) and Grade 2 (7·1) logs was appreciably less than that for Grade A logs (23·4).

Although a definite relation may exist between vigour of growth and extent of decay the present study did not reveal any consistent difference in the percentages of rot occurring in fast- and slow-growing trees. It should be mentioned that all the trees analysed occurred in either the slope or bench types which represent the better sites for the growth of Sitka spruce. No felled and bucked trees on the poorer sites, e.g. swamp type, were available for analysis. Undoubtedly, large forest areas placed under management would include stands on both good and poor sites and for complete coverage it will be necessary to extend the study to include the relationships of decay on all sites of commercial importance.

The preceding paragraphs deal with the economic factors in regard to decay which are essential in formulating management plans. The benefits to be derived from a thorough knowledge of decay are also of prime importance in the efficient utilization of overmature timber. Older trees contain varying amounts of decay and the results of pathological research provide the operators with information which assists in determining how far it is economically possible to go in the salvage of sound wood from diseased trees.

The tremendous demand for Sitka spruce in aeroplane construction required the forest authorities to consider every method of increasing production. In some areas a policy of selective logging was introduced which, for the most part, restricted the cutting to spruce in mixed stands of Sitka spruce, western hemlock, and western red cedar. Trees with external indications of decay (conks) which might indicate extensive areas of internal rot were not cut, since it was considered that the recovery of sound wood from such trees would not warrant the time and cost of felling and bucking. The present work has shown that there are no reliable external indications of decay in Sitka spruce except for the rot caused by *Fomes Pini*. In the case of this fungus fruiting bodies are usually present, indicating the present of rot. Further, it was evident from the spruce examined that rot seldom extended for any appreciable distance below the lowermost conk which was visible on the outside of diseased trees. Therefore, the extent of the rot column in diseased trees is indicated by the position of the conks on the outside. Analysis of 354 trees having fruiting bodies showed that, although the rot caused by *F. Pini* is the most important decay affecting Sitka spruce in total volume destroyed, it occurs primarily in the upper part of the trees. Further, in instances where the sporophores extended down to within 50 to 60 feet above the ground, and average of 92·7 per cent of the Grade 1 logs was free from all decay. The results of this work should lead to a better understanding of this type of decay in Sitka spruce, and bring about a closer utilization of infected trees which would yield substantial amounts of Grade 1 wood.

SUMMARY

The logs of 1,977 living trees of Sitka spruce on the Queen Charlotte Islands were scaled, graded, and analysed for loss through decay. These trees represented a gross merchantable volume of 13,963,223 board feet, of which 1,608,977 board feet or 11·5 per cent was destroyed by decay. Since all diseased trees were not cut on some areas examined, this figure is somewhat less than the actual loss on an area basis. The amount of decay recorded represents the loss on the basis of present standards of utilization.

The results demonstrate that a large part of the rot in mature and overmature trees on the slope and bench types occurs in the upper part of the trunks which would yield Grade 3 logs for reasons other than the presence of decay. The percentages of decay in 5,119,267 board feet of Grade 1 logs, 5,094,408 board feet of Grade 2 logs, and 3,754,548 board feet of Grade 3 logs amounted to 7·2, 7·1, and 23·4 respectively.

The problem of decay in overmature Sitka spruce is very complex because of the large number of fungi involved. During this study a total of 31 species of fungi was found causing decay in living trees. Among these is *Lentinus Kauffmanii* which was shown to be the cause of brown pocket rot. Although many wood destroyers attack living spruce, relatively few of these are of common occurrence. The following may be regarded as the major species: *Fomes Pini, Polyporus Schweinitzii, Fomes pinicola, Lentinus Kauffmanii, Trametes serialis, Poria microspora, Polyporus sulphureus, Fomes Laricis, Poria subacida,* and *Poria colorea.*

Except in the instances of red ring rot (*Fomes Pini*) no reliable, external indications of the presence and extent of the different decays in living trees were found. Broken tops and scars caused by falling trees usually indicate decay but provide little information as to its extent.

Although red ring rot was the most important decay in the amount of wood destroyed (4·6 per cent of the total volume measured), it was of little importance in the Grade 1 and Grade 2 logs recovered from diseased trees. Sporophores indicate the presence and extent of this decay in standing trees. Brown butt rot (*Polyporus Schweinitzii*) ranked second in importance to red ring rot, having destroyed 1·9 per cent of the gross merchantable volume. This decay was followed by brown crumbly rot (*Fomes pinicola*) which had decayed 1·5 per cent of the gross merchantable volume. Each of the remaining fungi had destroyed less than 1·0 per cent of the total volume measured. Brown pocket rot (*Lentinus Kauffmanii*) did not prove serious on the areas investigated. A majority of the loss from this decay occurred in Grade 1 logs. It is of importance to mention that there were 119 infections of the dry-rot fungi (*Trametes serialis* and *Poria microspora*) which had destroyed 0·7 per cent of the gross merchantable volume. These fungi are known to be destructive agents of timber in service.

The results indicated a relationship between age and decay. On the slope and bench types little decay was found in trees under 200 years of age. The average net periodic increment on a basis of gross merchantable volume began to decrease in trees from 250-300 years of age.

No consistent difference was apparent in the percentage of the gross merchantable volume lost through decay when the trees of the different age classes were divided into fast- and slow-growing groups.

The average gross and net merchantable volumes in the different diameter classes were similar for trees on the slope and bench types. Trees on the slope type contained appreciably more Grade 1 wood (an average of 1,000 board feet per tree) than those analysed on the bench type. A local volume table is presented which indicates the average gross and net merchantable volumes for Sitka spruce in the different diameter classes.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to all members of the logging industry, Provincial Forest Service, and Office of Timber Control, for their continued interest and support in this work. The writers wish to express their sincere appreciation in particular to Messrs. T. A. Kelley, President, and C. G. Dunham, formerly Forest Engineer, Kelley Logging Company Limited; T. B. Jackson, Manager of Timber Department, and P. L. Northcott, formerly Forest Engineer, Pacific Mills Limited; J. E.. Liersch, formerly Production Manager, Aero Timber Products Limited; and H. McQuillan, Manager, North Coast Timber Company; for the excellent co-operation and many courtesies which were extended to the investigators during the visits to these camps.

The authors also wish to express their gratitude to Mr. A. W. McCallum, Forest Pathologist, Division of Botany and Plant Pathology, for the valuable suggestions and advice given in the preparation of the manuscript.

BIBLIOGRAPHY

1. Baxter, D. V. and Varner, R.W. Importance of fungi and defects in handling Alaskan airplane spruce. Univ. of Michigan School of Forestry and Conservation Circ. 6. 1942.
2. Bier, J. E. and Nobles, M. K. Brown pocket rot of Sitka spruce. Can. J. Research, C, 24: 115-120. 1946.
3. Boyce, J. S. Decays and discolorations in airplane woods. U.S. Dept. Agr. Bull. 1128. 1923.
4. Boyce, J. S. Decay and other losses in Douglas fir in western Oregon and Washington. U.S. Dept. Agr. Tech. Bull. 286. 1932.
5. Cartwright, K. St. G. A decay of Sitka spruce timber, caused by *Trametes serialis,* Fr. Dept. Sci. Ind. Research (Brit.), Forest Products Research Bull. 4. 1930.
6. Cartwright, K. St. G. and Findlay, W. P. K. Principal decays of softwoods used in Great Britain. H.M.S.O., London. 1938.
7. Cary, N. L. Sitka spruce: its uses, growth, and management. U.S. Dept. Agr. Bull. 1062. 1922.
8. Colley, R. H. The effect of incipient decay on the mechanical properties of airplane timber. Phytopathology, 11:45. 1921.
9. Eades, H. W. British Columbia softwoods, their decays and natural defects. Can. Dept. Interior, Forest Service Bull. 80. 1932.
10. Englerth, G. H. Decay of western hemlock in western Oregon and Washington. Yale Univ., School of Forestry Bull. 50. 1942.
11. Hansbrough, J. R. and Englerth, G. H. The significance of the discolorations in aircraft lumber: Sitka spruce. U.S. Dept. Agr. Forest Pathology Special Release 21. 1944.
12. Hall, W. Moresby Forest. Survey and preliminary management plans. Unpublished report of the British Columbia Forest Service, Dept. Lands, Victoria. 1937.
13. Hirt, R. R. and Lowe, J. L. *Poria microspora* in house timbers. Phytopathology, 35: 217-218. 1925.
14. McCallum, A. W. Studies in Forest Pathology 1. Decay in balsam fir (*Abies balsamea,* Mill.) Can. Dept. Agr. Bull. 104 (n.s.) 1928.

15. Meyer, W. H. Yield of uneven-aged stands of Sitka spruce and western hemlock. U.S. Dept. Agr. Tech. Bull. 544. 1937.

16. Mounce, I. Studies in Forest Pathology II. The biology of *Fomes pinicola* (Sw.) Cooke. Can. Dept. Agr. Bull. 111 (n.s.). 1929.

17. Mounce, I. "Dote" disease of Sitka spruce (*Picea sitchensis* Carr.). *In* Report of the Dominion Botanist for the year 1925, p. 12. Ottawa. 1926.

18. Mounce, I. "Dote" disease of Sitka spruce (*Picea sitchensis* Carr.). *In* Report of the Dominion Botanist for the year 1926, pp. 20-23. Ottawa. 1927.

19. Nobles, M. K. A contribution toward a clarification of the *Trametes serialis* complex. Can. J. Research, C, 21:211-234. 1943.

20. Province of British Columbia. Report of the Forest Branch for the year ended December 31, 1938. Dept. Lands, Victoria. 1939.

21. Province of British Columbia. Report of the Forest Branch for the year ended December 31, 1939. Dept. Lands, Victoria. 1940.

22. Province of British Columbia. Forest Act. Victoria. 1941.

23. Province of British Columbia. Scaling lessons. Dept. Lands, Victoria. Revised 1942.

24. Province of British Columbia. Log Scale. Victoria. 1944.

25. Scheffer, T. C., Wilson, T. R. C., Luxford, R. F., and Hartley, C. The effect of certain heart rot fungi on the specific gravity and strength of Sitka spruce and Douglas fir, U.S. Dept. Agr. Tech. Bull. 779. 1941.

26. Spaulding, P. and Hansbrough, J. R. Decay in balsam fir in New England and New York. U.S. Dept. Agr. Tech. Bull. 872. 1944.

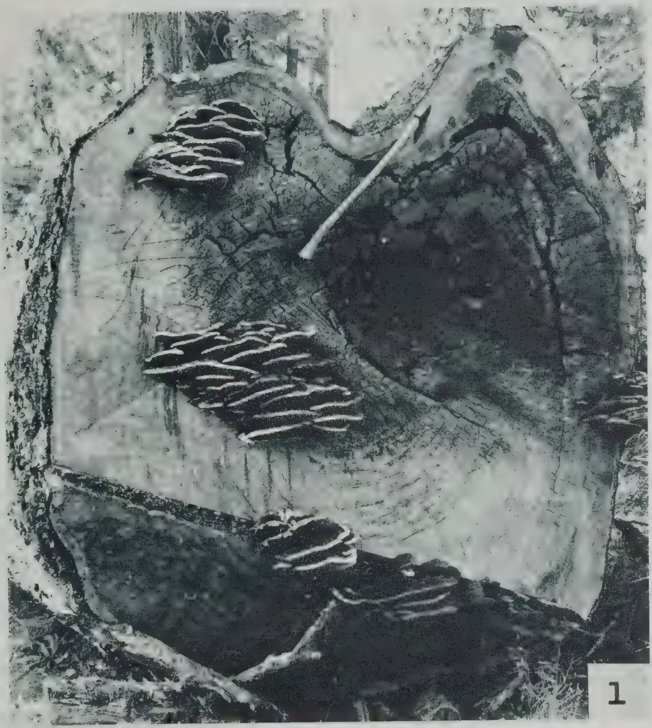
27. Taylor, R. F. Yield of second-growth western hemlock-Sitka spruce stands in southwestern Alaska. U.S. Dept. Agr. Tech. Bull. 412. 1934.

PLATE 1

Brown Butt Rot (*Polyporus Schweinitzii* Fr.) in Sitka Spruce on the Queen Charlotte Islands

FIGURE 1—Appearance of the decay on the stump end of a basal log. The decayed wood is reddish-brown, brittle, breaks into cubes on drying, and often has a turpentine or anise oil odour. In this instance conks were produced at the margin of the infected wood after the tree had been felled.

FIGURE 2—Appearance of the conks on an infected root which was exposed to the atmosphere. The conks are produced each year, and have a concentrically zoned, velvety, brown upper surface. The under surface is greenish, turning brown when bruised. When old the conks become corky and dark brown in colour.



1

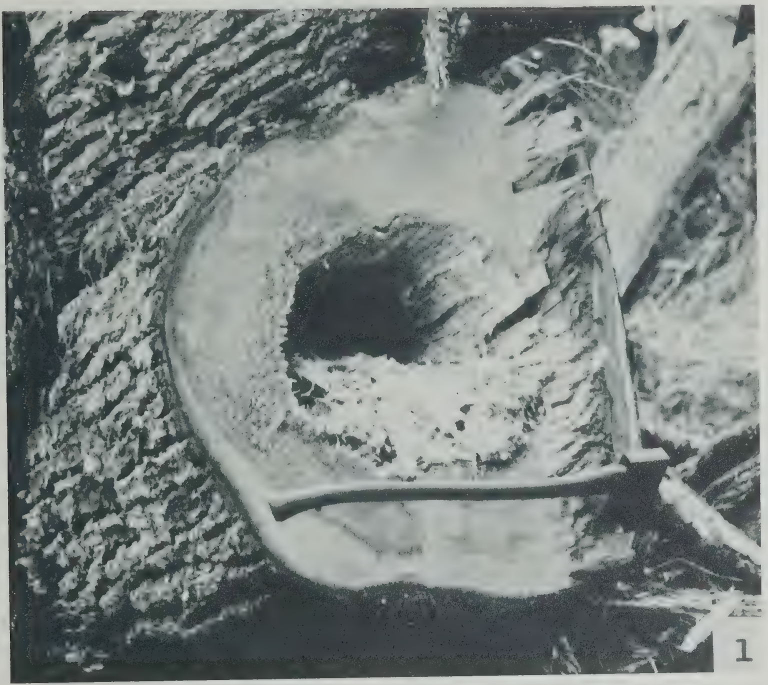
2

PLATE 2

Stringy Butt Rot (*Poria subacida* (Pk.) Sacc.)

FIGURE 1—Typical appearance of the white root and butt rots; the infected wood is reduced to a spongy mass of white fibres. These decays rarely extend for any appreciable distance along the trunks of the trees.

FIGURE 2—The fungous conks develop as flat, white, pore layers on the under side of diseased roots.



1

2

PLATE 3

Brown Pocket Rot (*Lentinus Kauffanii sp. nov.*) in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—Appearance of the decay on the stump end of a basal log. In the final stages of decay the isolated pockets of rot become so numerous that they develop into a solid mass of decay. In these instances the decay is usually present at the top end of the basal log.

FIGURE 2—Appearance of the decay at the top end of a basal log infected to the extent of the log shown in figure 1. Note the scattering of the pockets over the transverse surface, and the sharp demarcation between the sound and infected wood. In longitudinal section the individual pockets are broadly lens shaped, with an average length of 18 inches.

1

2

PLATE 4

Brown Pocket Rot in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—An infection consisting of 3 isolated pockets on the stump end of a basal log. Infections of this type did not extend to the top ends of the first logs.

FIGURE 2—An infection which had originated at a falling-tree scar.

1


2

PLATE 5

Conks of the fungus causing Brown Pocket Rot (*Lentinus Kauffmanii* sp. nov.) in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—The conks occur as small, white mushrooms at the margin of the infected wood. In this instance the conks developed on the cut surface of an infected tree.

FIGURE 2—Appearance of the conks on an infected log which had been on the ground for a period exceeding 50 years.

1

2

PLATE 6

Conk Rot (*Fomes pini* (Thore) Lloyd) in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—An infected tree with a column of conks on the upper part of the trunk. Most trees of this character contained one basal log free from this decay.

FIGURE 2—The individual conks are perennial, shelf-shaped to bracket-like. The upper surface is rough, brownish-black with concentric furrows. The undersurface or pore layer is lighter brown in colour.

FIGURE 3—The decayed wood has many small cavities which are separated by what appears to be sound wood. In the cavities the wood is reduced to a white mass of cellulose.

PLATE 6

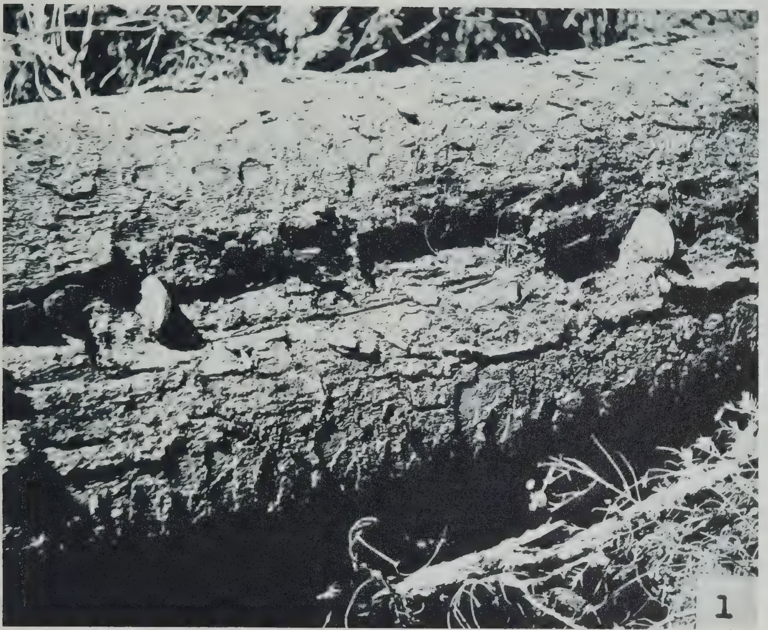
PLATE 7

Brown Crumbly Rot (*Fomes pinicola* (Swartz) Cke.) in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—The decay caused by this fungus was the most important brown trunk rot in volume of wood destroyed. Eighty-three per cent of the infections had occurred through scars as illustrated.

Note the two fungous conks which are present in the scarred area.

FIGURE 2—*F. pinicola* is one of the most common fungi, producing conks in abundance on dead trees and slash. The conks are hoof-shaped, perennial, with a woody texture. The upper surface is grey to black, frequently with a red margin. The undersurface is white to yellowish.


1

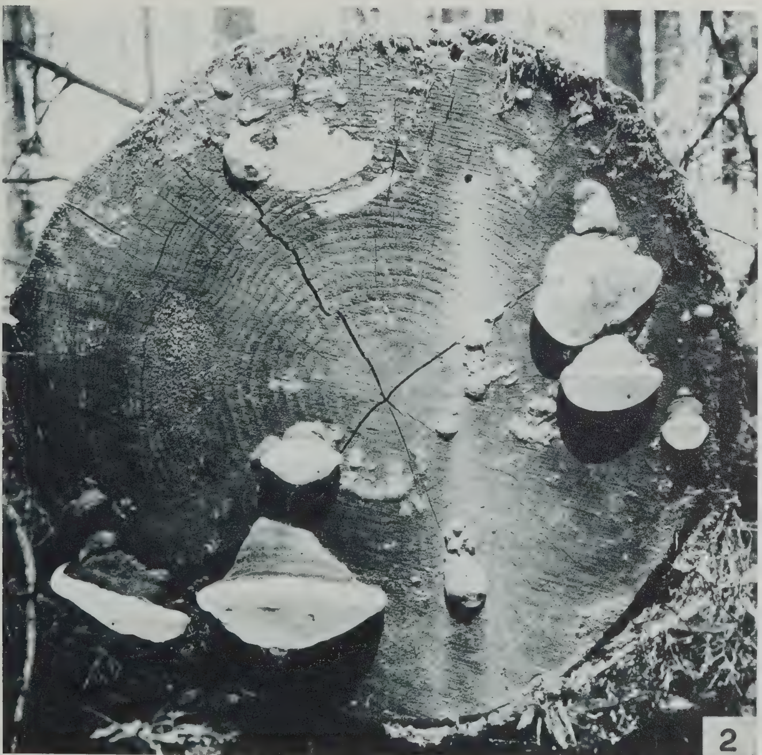

2

PLATE 8

Brown Trunk Rot (Dry Rot) caused by the fungi *Trametes serialis* Fr. and *Poria microspora* Overholts, in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—Conks of *T. serialis* which develop as white, pore layers on slash and on the undersurface of dead branches on living trees.

FIGURE 2—Conks of *P. microspora* which are similar in character and habits to the above, but have much smaller pores. Conks of this fungus appear to be very susceptible to insect attack, and are destroyed soon after they are formed.

FIGURE 3—Appearance of the decay caused by *T. serialis*. Wood in an advanced stage of decay breaks into cubes on drying. Note the absence of any distinct change in coloration which would assist in separating the diseased from the sound wood. The decay resulting from *P. microspora* is essentially the same as the above.

1

2

3

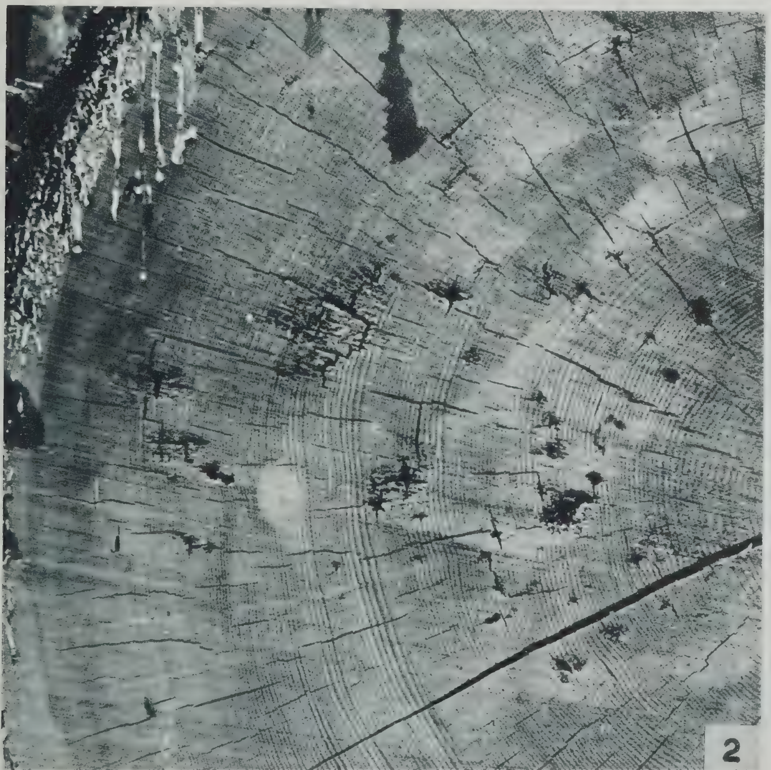
PLATE 9

Dry Rot in Sitka spruce on the Queen Charlotte Islands

FIGURE 1—Decay of *P. microspora* which had entered a basal log through a falling-tree scar. Many logs of the finest grade had infections of this type.

FIGURE 2—Decay of *T. serialis,* which frequently appears as scattered patches on the ends of logs.

1



2

PLATE 10

FIGURE 1—Conk of *Fomes laricis* (Jack.) Murr., which produces a brown trunk rot in Sitka spruce. The conks are perennial, white, hoof-shaped sometimes developing into a cylindrical shape up to 2 feet in length. The fungus produces a brown cubical rot which frequently has large, thick mycelial felts in the shrinkage cracks.

FIGURE 2—Conks of *Polyporus sulphureus* (Bull.) Fr., which produces a brown trunk rot in Sitka spruce. The annual shelf-like conks frequently occur in clusters overlapping one another. When fresh the conks have a bright orange-red upper surface and a sulphur-yellow undersurface. With age they become hard and brittle with a greyish to white colour.

1

2